Psychosocial predictors of energy underreporting in a large doubly labeled water study[1–3]

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ABSTRACT

Background: Underreporting of energy intake is associated with self-reported diet measures and appears to be selective according to personal characteristics. Doubly labeled water is an unbiased reference biomarker for energy intake that may be used to assess underreporting.

Objective: Our objective was to determine which factors are associated with underreporting of energy intake on food-frequency questionnaires (FFQs) and 24-h dietary recalls (24HRs).

Design: The study participants were 484 men and women aged 40–69 y who resided in Montgomery County, MD. Using the doubly labeled water method to measure total energy expenditure, we considered numerous psychosocial, lifestyle, and sociodemographic factors in multiple logistic regression models for prediction of the probability of underreporting on the FFQ and 24HR.

Results: In the FFQ models, fear of negative evaluation, weight-loss history, and percentage of energy from fat were the best predictors of underreporting in women ($R^2 = 0.09$); body mass index, comparison of activity level with that of others of the same sex and age, and eating frequency were the best predictors in men ($R^2 = 0.10$). In the 24HR models, social desirability, fear of negative evaluation, body mass index, percentage of energy from fat, usual activity, and variability in number of meals per day were the best predictors of underreporting in women ($R^2 = 0.22$); social desirability, dietary restraint, body mass index, eating frequency, dieting history, and education were the best predictors in men ($R^2 = 0.25$).

Conclusion: Although the final models were significantly related to underreporting on both the FFQ and the 24HR, the amount of variation explained by these models was relatively low, especially for the FFQ. *Am J Clin Nutr* 2004;79:795–804.

KEY WORDS Dietary assessment methods, epidemiologic methods, diet, nutrition surveys, biological markers, energy expenditure, doubly labeled water

INTRODUCTION

The primary measure of usual dietary intake in nutritional studies is self-report of diet. In part because of low cost and ease of administration, food-frequency questionnaires (FFQs), which measure a person's usual food intake over a specified time period, are widely used, especially for epidemiologic studies of diet and disease. Other self-reported methods of dietary assessment, such as 24-h dietary recalls (24HRs) or food records, are also used to characterize intake. The 24HR is the primary instrument used in dietary surveillance. However, numerous studies have shown that energy intake on these self-reported instruments is underreported when the doubly labeled water (DLW) method (1, 2) is used to estimate total energy expenditure (TEE) or when the ratio of energy intake to basal metabolic rate is used to characterize low-energy reporters (3). Because obesity rates are increasing in the United States (4), accurate description of energy intakes is essential to dietary surveillance and energy balance research.

Underreporting is more common among women than among men (5–11) and among older persons than among younger persons (7, 8, 10–13). Obesity, quantified by body mass index (BMI; in kg/m^2) or percentage of total body fat, is also associated with underreporting (6–12, 14–20). Compared with accurate reporters, underreporters tend to report being less physically active (7, 10–12, 20), being more likely to diet (7, 12, 16, 21), eating less fat as a percentage of energy intake (7, 9, 10, 20, 22, 23), and eating on fewer occasions (24).

Higher social desirability was associated with energy underreporting on an FFQ in women (25, 26). Taren et al (14) found that reporting accuracy on 3-d food records was significantly associated with both social desirability and body size dissatisfaction in women. Horner et al (26) found that women who perceived themselves to be thin rather than heavy tended to underreport their energy intake on an FFQ. Restrained eating, which is the conscious attempt to restrict the intake of calories, is also associated with underreporting (27, 28), as is high disinhibition, which is defined as the loss of self-control in eating behavior in response to dysphoric emotions or counter-regulation of diet (28).

Although some studies of underreporting used the DLW method to estimate energy requirements for weight maintenance (6, 14, 15, 19, 21–23, 27), others relied on the ratio of reported

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energy intake to basal metabolic rate calculated from height and weight (7–12, 18, 20, 29) or on other methods (5, 13, 16, 17, 25, 30). Furthermore, most studies of underreporting considered the effects of only one predictor variable at a time. The Observing Protein and Energy Nutrition (OPEN) Study, in which the DLW method was used to measure TEE and in which psychosocial, behavioral, and sociodemographic data were collected from 484 women and men, provides a unique opportunity to assess underreporting on both FFQs and 24HRs by using a multivariate approach. Identification of factors systematically related to underreporting may facilitate the development of more accurate measures and of methods to correct for errors in reporting.

SUBJECTS AND METHODS

Study population

Details of the OPEN Study have been described previously (31). Briefly, study participants were recruited from a random sample of 5000 households with telephone numbers listed in the white pages and a household member aged 40–69 y in the Maryland metropolitan area of Washington, DC (Montgomery County). Of 837 eligible participants, 614 initially agreed to participate in the study, and 484 (261 men and 223 women) attended the first visit. The study was approved by the Special Studies Institutional Review Board of the National Cancer Institute.

Procedures

Participants in the OPEN Study completed 3 visits over a period of ≈3 mo from September 1999 to March 2000, and only 2 participants failed to complete the study. After the initial telephone contact and recruitment, the participants were mailed an introductory letter and FFQ to complete. At visit 1, the participants gave written informed consent, had their FFQs reviewed, were administered the first 24HR, completed a physical activity questionnaire, had height and weight measured, and received their first dose of DLW. The BMI calculated at this visit was used in all analyses.

Visit 2 was scheduled 11–14 d after visit 1. At visit 2, the participants completed the DLW protocol; were weighed; completed a health questionnaire that consisted of a dietary screener questionnaire, questions about smoking, and the Fear of Negative Evaluation Scale (32); and answered questions regarding Stunkard-Sorenson body silhouettes (33).

Visit 3 occurred ≈3 mo after visit 1. Before the visit, the participants were mailed a second FFQ to complete and bring to the clinic. At this visit, weight was measured, a second 24HR was administered, and participants completed a supplemental questionnaire, which consisted of the Three-Factor Eating Questionnaire (34), the Marlowe-Crowne Social Desirability Questionnaire (35–37), and questions about dieting and weight loss.

In addition to the main study, a small substudy was conducted to determine between-subject and within-subject variations in TEE. Fourteen men and 11 women in the main study agreed to be dosed with DLW a second time at visit 2.

Energy intake

The FFQ that was used was the National Cancer Institute's newly developed Diet History Questionnaire (Internet: http://riskfactor.cancer.gov/dhq; accessed 28 August 2003). Trained interviewers administered the 24HR by using a standardized five-pass method, which was developed by the US Department of Agriculture (38). The Food Intake Analysis System (version 3.99; Human Nutrition Center, University of Texas Health Science Center, School of Public Health, Houston, TX) was used to analyze the 24HR data. Energy intakes from the first FFQ were used because those from the second FFQ were lower due perhaps to fatigue from being queried about usual long-term intake a few months before. The average of the two 24HRs was used to better reflect usual energy intake.

Psychosocial factors

Fear of Negative Evaluation Scale

A person with a fear of negative evaluation is worried about being perceived in an unfavorable way by others or about doing the "wrong" things. In the OPEN Study, a brief version of the Fear of Negative Evaluation Scale, which consisted of twelve 5-point items measuring the level of concern a person has about the opinion another person has of her or him, was self-administered. The brief scale is highly correlated with the original scale ($r = 0.96$) and has high internal reliability (Cronbach's $\alpha = 0.90$) and test-retest reliability ($r = 0.75$) (32).

Stunkard-Sorensen body silhouettes

The Stunkard-Sorensen body silhouettes consist of drawings of 9 different men or women of increasing body size (33). The participants were asked which figure they perceived to be closest to their current body size, which they perceived to be the healthiest, and which they would like to have. Differences between each participant's perceived current body silhouette and what he or she perceived to be healthy and ideal were computed.

Marlowe-Crowne Social Desirability Scale

Social desirability is the tendency of some persons to respond to questionnaires or interviews with what is perceived to be a socially appropriate response rather than an objective response. In this instrument, social desirability is conceptualized as a stable personality trait, which does not change over time or with different circumstances. The Marlowe-Crowne Social Desirability Scale consists of 33 true-false items; a higher score indicates greater social desirability. This scale has been shown to be internally consistent (Kuder-Richardson formula 20 coefficient = 0.88) and to have good test-retest reliability ($r = 0.89$) (35). A brief, 20-item version of this scale (36, 37) was self-administered in the present study. The consistency of the 20-item version approaches that of the original scale (36).

Three-Factor Eating Questionnaire

Three dimensions of eating behavior are measured by this questionnaire: restraint, which is the conscious restriction of food intake; disinhibition, which is the loss of self-control in eating behavior; and hunger, which is the desire to eat (34). The questionnaire comprises 36 true-false items and fifteen 4-point items. The internal reliability of the scale has been shown to be high ($r = 0.93$ for restraint, 0.91 for disinhibition, and 0.85 for hunger). The scale has also been shown to distinguish dieters from nondieters (34).

Other factors

The physical activity questionnaire from the National Health and Nutrition Examination Survey (NHANES), 1999–2000

(Internet: http://www.cdc.gov/nchs/data/nhanes/spq-pa.pdf; accessed 28 August 2003), was administered to the participants by an interviewer. This questionnaire asks about the types, frequency, intensity, and duration of activities the study participant has engaged in over the past 30 d. From this, the number of minutes per week the participant spent doing transportation-related activities, household activities, or other moderate or vigorous activities was computed. The number of minutes per week was multiplied by a factor of 4.0 for transportation-related activities, by 4.5 for other moderate activities (including household activities), and by 7.0 for vigorous activities to calculate metabolic equivalents per week. Because of the skewed distribution of this variable, a natural log transformation was used in all analyses. Participants who had ≥150 min of moderate activity (including household activities and transportation-related activities)/wk or 60 min of vigorous activity/wk were considered to have met the recommended level of activity set forth in *Healthy People 2010* (39). The participants were also asked about their usual level of activity (sitting, standing or walking, lifting light loads, lifting heavy loads). The 2 lifting categories were combined. The participants were asked to compare their activity level to that of other persons of their age, ie, to determine whether their level was more, less, or the same as that of others.

The health questionnaire contained questions on smoking history; the number of, and variability in the number of, snacks and meals eaten daily; and the frequency of consumption of meals not prepared in the home. The questionnaire also contained 4 questions to assess nutrition salience: how often the participants ate foods that were not good for them, how often they tried to eat only healthy foods at social events, how often they considered whether a food was healthy when choosing food at a restaurant, and how often they considered whether a food was healthy when eating at home (A Kristal, personal communication, 2002).

Statistical analyses

In this article, we characterized participants as underreporters, accurate reporters, or overreporters. Although it is possible to use a continuous measure to quantify the level of underreporting, it is unclear whether an interval scale would be appropriate for these data. Therefore, we chose to look at qualitative differences by classifying participants into categories and modeling the probability of a participant being an underreporter or accurate reporter, rather than assuming a linear relation between the change in a covariate and a corresponding change on an interval scale. Additionally, using categories minimizes the effect of outliers and allows for easier interpretation of the results.

Under energy balance, TEE is equivalent to energy intake. If TEE is used to represent energy intake and if self-reported energy intake is assumed to be unbiased, then the ratio of reported intake to TEE would be expected to vary around the value of 1. Therefore, inaccurate reporters (underreporters and overreporters) were defined as participants whose values were outside the 95% CI around the log ratio of reported intake to TEE under the assumption of unbiased reporting.

A framework of underreporting of energy intake (**Figure 1**) was developed to guide subsequent analyses. This framework specifies 4 domains that affect the accuracy of self-reports of diet: psychosocial factors, lifestyle factors that affect energy balance, skills and knowledge, and characteristics of the diet. The variables listed for each domain in the figure were considered in the statistical analyses.

The chi-square test was used to compare the characteristics of the study participants by sex. In univariate analyses to compare underreporters with accurate reporters, *t* tests were used for continuous variables (age, BMI, psychosocial variables, nutrition salience, metabolic equivalents per week, and percentage of energy from fat), and chi-square tests were used for categorical variables (smoking status, education, diet history, and variability of diet).

To develop multivariate models, logistic regression was used to model the effects of psychosocial factors, energy balance, characteristics of diet, and knowledge on the odds of underreporting. First, variables were considered one at a time in logistic regression models. All psychosocial variables, age, education, and all other variables with a univariate test P value ≤ 0.25 were considered for inclusion in the multiple logistic regression models (40). Because of correlations between the variables within the domains, the most highly significant variable within a domain was considered first; the correlated variables were then substituted for that variable to determine whether the model was improved. Four models were fit by using a backward regression procedure, first including all the potential predictor variables in the model and then with the variables removed one at a time, until the likelihood ratio test statistic exceeded a prespecified cutoff. In multistep model selection procedures, the actual distribution of the test statistic at each step is unknown (40). The use of a nominal α level of 0.05 to calculate the cutoff has been shown to be too stringent, because important variables are often excluded from the model when this α level is used (40, 41). For this reason, we used a cutoff corresponding to the nominal 0.10 significance level of the likelihood ratio test. Values on the order of 0.10–0.25 have been recommended for this procedure (40, 41). Two-way interactions between psychosocial variables were considered in the models. After determination of a preliminary final model, fractional polynomials (42) and smooth scatterplots were used to determine whether the model was linear on the logit scale for continuous variables. The form of the continuous variable in the model (eg, linear or quadratic) was determined by minimizing Akaike's Information Criterion (43). The generalized coefficient of determination statistic, ie, R^2, was used to describe the proportion of variability explained by the model. The R^2 value and the R^2 rescaled to the maximum value of R^2 (which may be <1 for some logistic models) were computed for all of the models (44). The Hosmer and Lemeshow goodness-of-fit test (40) was used to assess goodness of fit for all models. Observations were considered to be potential outliers if the change in deviance statistic was >3.84 (40). All analyses were performed by using SAS software (version 8.2; SAS Institute Inc, Cary, NC).

RESULTS

The characteristics of the study participants are presented in **Table 1**. The study sample was 46% female, and the age distribution did not differ significantly by sex. Most of the participants were non-Hispanic whites and had never smoked. The population was well educated: 72% of the men and 52% of the women had at least a college degree. Sixty percent of the women and 76% of the men were overweight or obese; 29% each of the women and the men were obese.

Relative to TEE, energy was underreported on both the FFQ and the 24HRs by both the men and the women (**Table 2**).

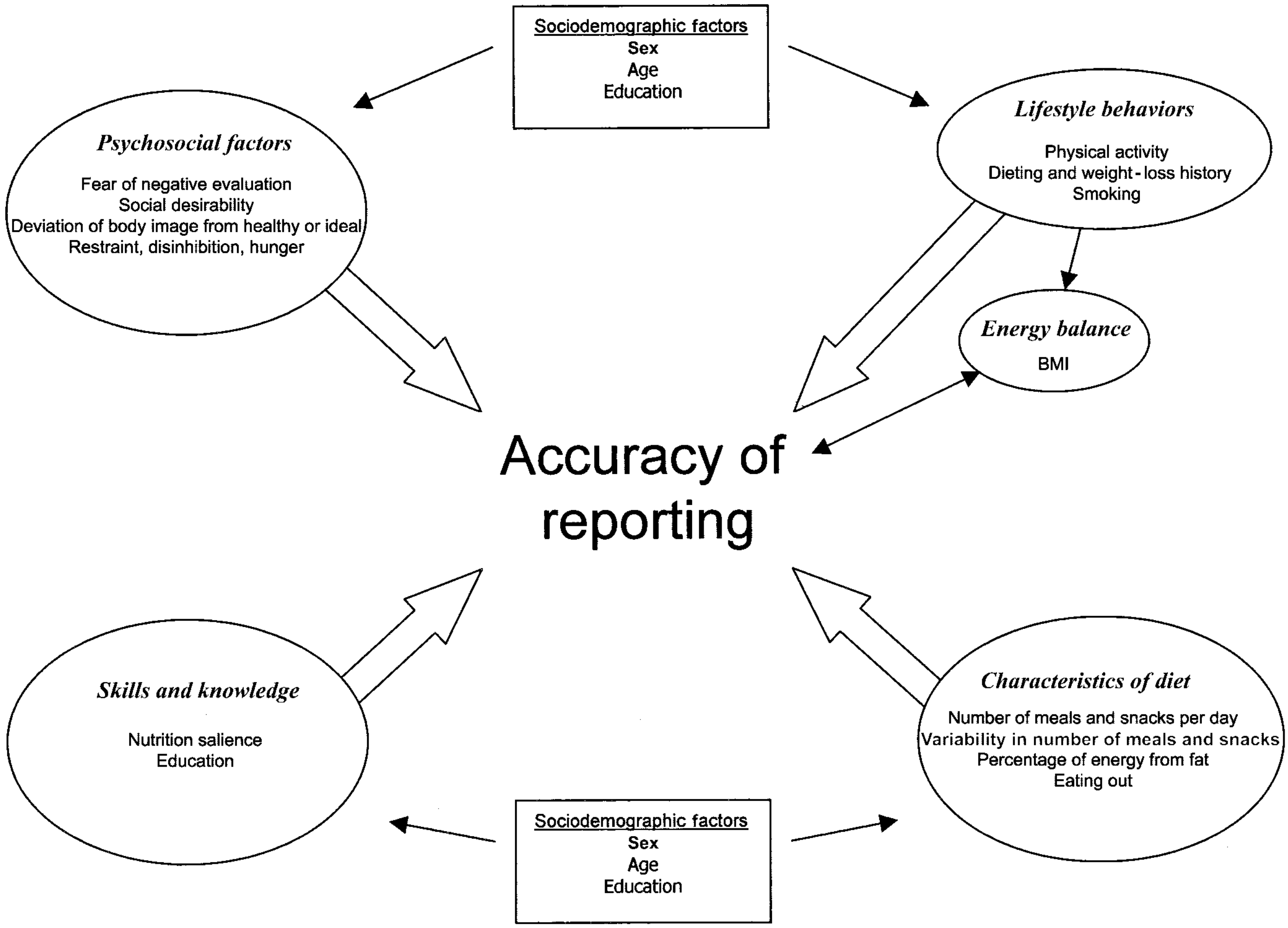

FIGURE 1. Analytic framework of underreporting of energy intake. Predictor variables were grouped into 4 domains that affect accuracy of reporting: psychosocial factors, lifestyle behaviors that affect energy balance, skills and knowledge, and characteristics of diet. BMI is affected by lifestyle behaviors and has been consistently reported to be associated with underreporting; however, this association may result from a tendency of underreporters to have a higher BMI because of their inability to estimate their energy intake.

Compared with the median TEE, energy intake in the men was underreported by 11% on the 24HRs and by 30% on the first FFQ. In the women, energy intake was underreported in comparison with the median TEE by 17% and 34% on the 24HRs and the first FFQ, respectively. Twenty-two percent of the women and 21% of the men were classified as underreporters on the 24HRs; 1.0% of the women and 1.6% of the men were classified as overreporters. On the first FFQ, 49% of the women and 50% of the men were classified as underreporters; 1.9% of the women and 2.5% of the men were classified as overreporters. Thirteen percent of the women and 14% of the men were classified as underreporters on both the FFQ and the 24HRs; none of the participants were classified as overreporters on both instruments. Because the proportion of overreporters was so small, they were excluded from further analyses.

The characteristics of underreporters and accurate reporters on the FFQ are presented in **Table 3**. Among the women, perceived body size from the Stunkard-Sorensen silhouettes and percentage of energy from fat were significantly higher and lower, respectively, in the underreporters than in the accurate reporters. Among the men, BMI and perceived body size were significantly higher in the underreporters; the underreporters also had a significantly larger discrepancy between their perceived and ideal body sizes than did the accurate reporters. The men who were underreporters on the FFQ were also significantly more likely than the accurate reporters to have reported past dieting, to have a history of weight loss, and to consider themselves to be more active than other men of the same age.

The characteristics of underreporters and accurate reporters on the 24HRs are presented in **Table 4**. Compared with the accurate reporters of the same sex, the female underreporters reported diets with a significantly lower percentage of energy from fat, had significantly larger discrepancies between their perceived body size and both their healthy and ideal body sizes, and were significantly more likely to have lost ≥10 lb (4.5 kg) multiple times and to report that the number of meals they ate varied from day to day. The male underreporters had significantly higher BMI and perceived body size than did the accurate reporters of the same sex; the perceived body size of the male underreporters also deviated significantly more from what they considered to be healthy or ideal. Compared with the accurate reporters of the same sex, the male underreporters scored significantly higher on the restraint scale and were significantly more likely to have dieted multiple times, to have lost weight, and to report eating <5 times/d.

TABLE 1
Characteristics of study subjects

	Women (n = 223)	Men (n = 261)
	n (%)	
Age (y)		
40–49	88 (39.5)	96 (36.8)
50–59	82 (36.8)	90 (34.5)
60–69	53 (23.8)	75 (28.7)
BMI (kg/m^2)[1]		
<25.0	88 (39.5)	62 (23.8)
25.0–29.9	71 (31.8)	123 (47.1)
>29.9	64 (28.7)	76 (29.1)
Race[1]		
Non-Hispanic white	173 (77.6)	226 (86.6)
Non-Hispanic black	23 (10.3)	7 (2.7)
Asian	11 (4.9)	15 (5.7)
Hispanic white	4 (1.8)	7 (2.7)
Other or unknown	12 (5.4)	6 (2.3)
Smoking status		
Current	29 (13.0)	23 (8.8)
Former	60 (26.9)	88 (33.7)
Never	132 (59.2)	150 (57.5)
Unknown	2 (0.9)	0 (0.0)
Education level[1]		
High school or less	43 (19.3)	21 (8.0)
Some college	58 (26.0)	52 (19.9)
College graduate	59 (26.5)	92 (35.2)
Postgraduate	58 (26.0)	95 (36.4)
Unknown	5 (2.2)	1 (0.4)

[1] Significant difference between the sexes ($P < 0.05$, chi-square test).

Univariate logistic regression models confirmed the results reported in Tables 3 and 4. Factors that had a P value ≤ 0.25 in these models, as well as all psychosocial and sociodemographic factors, were considered for inclusion in the multiple logistic regression models by using the framework in Figure 1 to group the variables. On the basis of smooth scatterplots and fractional polynomials, it was determined that BMI was best modeled by using a second-degree polynomial for the FFQ and 24HR models, with both BMI and BMI^2 in the model. Fear of negative evaluation and restraint were best fit by categorizing participants as "low" or "high" by splitting at the median.

The odds ratios of underreporting on the FFQ from the final multiple logistic regression models for the women and the men are presented in **Table 5**. For continuous variables, the odds ratio associated with the change from the median of each of the 3 quartiles to the median of the reference quartile (first or fourth) is presented. In the women, a lower percentage of energy from fat, a weight-loss history of $\geq$10 lb (4.5 kg), and a high fear of negative evaluation were associated with higher odds of underreporting in the final multivariate model. In the men, a higher BMI and a report of eating <5 times/d were associated with higher odds of being an underreporter, and a perception of being less active than other men of the same age was associated with lower odds of underreporting. The associated R^2 values for the FFQ models were 0.09 for the women and 0.10 for the men; rescaled to the maximum R^2, the values were 0.12 and 0.14, respectively. These statistics may be overstated because of the model selection procedure used. The Hosmer and Lemeshow goodness-of-fit tests indicated that the models fit well (all P values > 0.05).

The odds ratios of underreporting on the 24HRs from the multiple logistic regression models are presented in **Table 6**. In the women, the predictors in the final multivariate model indicated that the odds of underreporting were higher for those with a higher BMI, those for whom the number of meals varied from day to day, those for whom usual daily activities included primarily lifting or standing rather than sitting, and those who reported a low percentage of energy from fat. Additionally, higher social desirability and high fear of negative evaluation were associated with higher odds of underreporting. In the men, higher BMI, reported eating of <5 times/d, repeated dieting of $\geq$6 times, and higher education levels were associated with higher odds of underreporting. There was an effect modification between restraint and social desirability. High restraint was associated with higher odds of underreporting in the men when social desirability was held at the median. When restraint was low, higher social desirability scores were associated with higher odds of underreporting; however, when restraint was high, higher social desirability scores were associated with lower odds of underreporting. The associated R^2 values for the 24HR models were 0.22 for the women and 0.25 for the men; adjusted for the maximum R^2, the values were 0.33 and 0.38, respectively. The Hosmer and Lemeshow goodness-of-fit tests indicated that the models fit well.

According to the adopted criterion for outliers defined above, 2 participants (one man and one woman) were found to be influential in the FFQ models; 18 participants (9 men and 9 women) were influential in the 24HR models. All the influential participants were underreporters. When the influential participants were eliminated, all model coefficients tended to become more extreme (ie, deviated from zero, in many cases by >10%). Although the influential participants were outliers in the model space, their values for individual covariates were not unreasonable. Therefore, all of the results are presented with these observations included. Because eliminating them strengthened the conclusions of our models, it is more conservative to keep them in our analysis. Particularly for the 24HR models, excluding the influential participants substantially increases the amount of variability explained.

TABLE 2
Energy intakes of study subjects[1]

	Women (n = 223)	Men (n = 261)
	J	
From DLW (TEE)	9.55 (8.50–10.57) [206]	11.77 (10.68–13.16) [245]
From 24HRs	7.91 (6.59–9.45) [223]	10.45 (8.80–12.21) [261]
From FFQ	6.34 (4.91–8.33) [222]	8.18 (6.43–10.67) [260]

[1] All values are medians; 25th–75th percentiles in parentheses; n in brackets. DLW, doubly labeled water; TEE, total energy expenditure; 24HRs, 24-h dietary recalls; FFQ, food-frequency questionnaire.

DISCUSSION

This large DLW study showed underreporting on both the FFQ and 24HR dietary assessment methods. By examining potential predictor variables in multiple logistic regression models representing 4 domains (Figure 1), we were able to explore which factors remain associated with underreporting while taking into account the interdependency among multiple factors. Considering variables one at a time, we found that at least one variable from all of the domains, except skills and knowledge, was asso-

TABLE 3

Characteristics of underreporters (URs) and accurate reporters (ARs) on the food-frequency questionnaire (FFQ)[1]

	Women		Men	
	ARs (n = 101)	URs (n = 101)	ARs (n = 117)	URs (n = 121)
Age (y)	52.46 ± 0.79[2]	53.12 ± 0.82	53.73 ± 0.86	54.44 ± 0.75
BMI (kg/m^2)	26.82 ± 0.55	28.25 ± 0.63[3]	27.15 ± 0.40	28.92 ± 0.40[4]
Physical activity, log (METs/wk + 1)	6.51 ± 0.20	6.83 ± 0.15	6.78 ± 0.15	6.89 ± 0.12
Fear of negative evaluation[5]	29.65 ± 0.73	31.36 ± 0.88	29.53 ± 0.77	28.60 ± 0.60
Social desirability[6]	12.28 ± 0.40	12.71 ± 0.38	11.49 ± 0.38	12.24 ± 0.34
Perceived body size[7]	4.34 ± 0.13	4.68 ± 0.12[4]	5.04 ± 0.12	5.39 ± 0.11[4]
Deviation from healthy size	1.08 ± 0.11	1.27 ± 0.11	1.02 ± 0.11	1.25 ± 0.10
Deviation from ideal size	1.10 ± 0.09	1.33 ± 0.10[3]	0.89 ± 0.10	1.18 ± 0.09[4]
Eating behavior[8]				
Restraint	9.02 ± 0.49	10.15 ± 0.46[3]	7.30 ± 0.40	7.65 ± 0.37
Disinhibition	5.93 ± 0.40	6.19 ± 0.39	4.75 ± 0.29	5.09 ± 0.27
Hunger	4.14 ± 0.32	4.40 ± 0.33	4.34 ± 0.31	4.07 ± 0.26
Nutrition salience[9]	10.80 ± 0.25	11.02 ± 0.26	10.05 ± 0.24	10.20 ± 0.23
Fat (% of energy)[10]	31.49 ± 0.68	28.33 ± 0.72[4]	30.63 ± 0.61	30.91 ± 0.65
Education level (%)				
High school or less	19.2	20.4	8.5	8.3
Some college	25.3	25.5	21.4	19.2
College graduate	33.3	25.5	36.8	31.7
Postgraduate	22.2	28.6	33.3	40.8
Smoking status (%)				
Current	12.9	13.0	8.5	8.3
Former	26.7	28.0	36.8	33.9
Never	60.4	59.0	54.7	57.9
Met recommended activity level (%)	64.3	69.7	68.1	67.8
Activity level compared with that of others[11] (%)[12]				
Less	21.9	19.8	26.8	13.8
Same	37.5	38.5	42.0	39.7
More	40.6	41.8	31.3	46.6
Usual activity (%)				
Lifting	30.7	23.8	21.6	17.5
Standing	43.6	51.5	46.6	50.8
Sitting	25.7	24.8	31.9	31.7
Ever dieted (%)	74.3	80.2	52.1	64.5[13]
Times dieted (%)				
0	25.7	19.8	47.9	35.5
1–2	18.8	14.9	23.1	27.3
3–5	25.7	26.7	17.9	19.8
≥6	29.7	38.6	11.1	17.4
Lost 10 lb (%)	46.5	58.4[14]	33.3	48.3[13]
Times in which 10 lb was lost (%)[12]				
0	53.5	41.6	66.7	51.7
1–2	21.8	24.8	15.8	25.4
≥3	24.8	33.7	17.5	22.9
Number of meals varies (%)	27.7	27.7	22.2	18.3
Number of snacks varies (%)	53.5	48.5	52.1	48.8
Eat out ≥1 time/wk (%)	68.0	74.5	75.2	80.0
Eat <5 times/d (%)	51.5	55.4	59.0	70.2[14]

[1] METs, metabolic equivalents. 10 lb = 4.5 kg.

[2] $\bar{x}$ ± SE (all such values).

[3] Nearly significantly different from ARs, $P < 0.10$ (t test).

[4] Significantly different from ARs, $P < 0.05$ (t test).

[5] On a brief version of the Fear of Negative Evaluation Scale; possible values from 12 to 60.

[6] On a brief version of the Marlowe-Crowne Social Desirability Scale; possible values from 0 to 20.

[7] Perceived body size from the Stunkard-Sorensen silhouettes (possible values from 1 to 9). Deviation from healthy size represents the difference in values between what the participant perceived to be the healthiest body size and his or her perceived body size (perceived minus healthy). Deviation from ideal size represents the difference in values between the body size the participant would like to have and his or her perceived body size (perceived minus ideal).

[8] From the Three-Factor Eating Questionnaire; possible values for restraint, disinhibition, and hunger were 0–21, 0–16, and 0–14, respectively.

[9] Possible values from 4 to 16.

[10] From the FFQ.

[11] Other persons of the same sex and age.

[12] Significant difference between ARs and URs among the men, $P < 0.05$ (chi-square test).

[13] Significantly different from ARs, $P < 0.05$ (chi-square test).

[14] Nearly significantly different from ARs, $P < 0.10$ (chi-square test).

TABLE 4

Characteristics of underreporters (URs) and accurate reporters (ARs) on 24-h dietary recalls (24HRs)[1]

	Women		Men	
	ARs (n = 158)	URs (n = 46)	ARs (n = 190)	URs (n = 51)
Age (y)	52.61 ± 0.64[2]	53.54 ± 1.13	53.94 ± 0.65	54.57 ± 1.11
BMI (kg/m^2)	27.18 ± 0.49	29.10 ± 0.79[3]	27.61 ± 0.32	29.53 ± 0.58[4]
Physical activity, log (METs/wk + 1)	6.68 ± 0.14	6.46 ± 0.34	6.78 ± 0.11	7.09 ± 0.21
Fear of negative evaluation[5]	30.07 ± 0.65	32.66 ± 1.14[3]	29.53 ± 0.55	27.35 ± 0.95[3]
Social desirability[6]	12.30 ± 0.31	13.29 ± 0.55	11.77 ± 0.28	12.49 ± 0.53
Perceived body size[7]	4.42 ± 0.10	4.80 ± 0.15[3]	5.12 ± 0.09	5.57 ± 0.15[4]
Deviation from healthy size	1.09 ± 0.08	1.43 ± 0.16[4]	1.07 ± 0.09	1.39 ± 0.13[4]
Deviation from ideal size	1.14 ± 0.08	1.48 ± 0.15[4]	0.96 ± 0.08	1.35 ± 0.12[4]
Eating behavior[8]				
Restraint	9.33 ± 0.36	10.23 ± 0.80	7.16 ± 0.31	8.82 ± 0.53[4]
Disinhibition	5.88 ± 0.31	6.60 ± 0.59	4.82 ± 0.22	5.02 ± 0.46
Hunger	4.41 ± 0.25	4.05 ± 0.57	4.20 ± 0.22	3.76 ± 0.37
Nutrition salience[9]	10.81 ± 0.20	11.11 ± 0.37	10.01 ± 0.19	10.63 ± 0.35
Fat (% of energy)[10]	32.63 ± 0.60	28.91 ± 1.19[4]	31.62 ± 0.55	31.65 ± 0.99
Education level (%)				
High school or less	17.8	27.9	9.5	3.9
Some college	26.1	25.6	19.6	21.6
College graduate	29.9	25.6	36.0	27.5
Postgraduate	26.1	20.9	34.9	47.1
Smoking status (%)				
Current	12.1	17.4	8.4	7.8
Former	25.5	30.4	34.7	33.3
Never	62.4	52.2	56.8	58.8
Met recommended activity level (%)	68.0	60.9	65.6	76.5
Activity level compared with that of others[11] (%)				
Less	20.4	26.2	21.0	20.0
Same	38.8	31.0	39.2	46.0
More	40.8	42.9	39.8	34.0
Usual activity (%)				
Lifting	25.9	34.8	18.6	17.6
Standing	45.6	50.0	50.5	45.1
Sitting	28.5	15.2	30.9	37.3
Ever dieted (%)	75.9	82.6	55.0	70.6[12]
Times dieted (%)[13]				
0	24.1	17.4	45.0	29.4
1–2	17.1	17.4	24.9	29.4
3–5	27.2	23.9	20.6	9.8
≥6	31.6	41.3	9.5	31.4
Lost 10 lb (%)	48.1	67.4[12]	37.8	53.1[12]
Times in which 10 lb was lost (%)[14]				
0	51.9	32.6	62.2	46.9
1–2	25.3	19.6	20.0	24.5
≥3	22.8	47.8	17.8	28.6
Number of meals varies (%)	21.5	47.8[12]	19.6	25.5
Number of snacks varies (%)	52.5	47.8	50.0	52.9
Eat out ≥1 time/wk (%)	71.6	72.7	78.7	72.9
Eat <5 times/d (%)	52.5	58.7	58.9	86.3[12]

[1] METs, metabolic equivalents. 10 lb = 4.5 kg.

[2] $\bar{x}$ ± SE (all such values).

[3] Nearly significantly different from ARs, $P < 0.10$ (t test).

[4] Significantly different from ARs, $P < 0.05$ (t test).

[5] On a brief version of the Fear of Negative Evaluation Scale; possible values from 12 to 60.

[6] On a brief version of the Marlowe-Crowne Social Desirability Scale; possible values from 0 to 20.

[7] Perceived body size from the Stunkard-Sorensen silhouettes (possible values from 1 to 9). Deviation from healthy size represents the difference in values between what the participant perceived to be the healthiest body size and his or her perceived body size (perceived minus healthy). Deviation from ideal size represents the difference in values between the body size the participant would like to have and his or her perceived body size (perceived minus ideal).

[8] From the Three-Factor Eating Questionnaire; possible values for restraint, disinhibition, and hunger were 0–21, 0–16, and 0–14, respectively.

[9] Possible values from 4 to 16.

[10] From the 24HRs.

[11] Other persons of the same sex and age.

[12] Significantly different from the ARs, $P < 0.05$ (chi-square test).

[13] Significant difference between ARs and URs among the men, $P < 0.05$ (chi-square test).

[14] Significant difference between ARs and URs among the women, $P < 0.05$ (chi-square test).

TABLE 5
Odd ratios (ORs) of underreporting on the food-frequency questionnaire from the multiple logistic regression models[1]

	OR (95% CI)[2]	P[3]
Women		
Fat (% of energy), compared with Q4		
Q1	3.34 (1.58, 7.06)	0.0010
Q2	2.15 (1.34, 3.46)	
Q3	1.54 (1.18, 2.01)	
Lost 10 lb?, yes compared with no	2.03 (1.12, 3.68)	0.0187
Fear of negative evaluation, high compared with low	1.88 (1.04, 3.39)	0.0345
Men		
BMI,[4] compared with Q1		
Q2	1.85 (1.25, 2.73)	0.0017
Q3	2.64 (1.46, 4.77)	
Q4	3.75 (1.76, 8.02)	
Times subject are per day, <5 compared with ≥5)	1.87 (1.05, 3.33)	0.0327
Activity level,[5] compared with same		
Less active	0.53 (0.25, 1.13)	0.0059
More active	1.79 (0.96, 3.33)	

[1] Q, quartile. 10 lb = 4.5 kg.
[2] Because analytic distributions for the estimated variables of the final model were unknown, the nominal 95% CIs are presented.
[3] Nominal P value based on likelihood-ratio test statistic. The value given on the first line for each variable corresponds to the overall P value for that variable.
[4] BMI estimates were calculated by using the model estimates for BMI + BMI^2, with the median of the quartile used to generate the OR.
[5] Compared with that of other men of the same age.

TABLE 6
Odds ratios (ORs) of underreporting on the 24 h dietary recalls (24 HRs) from the multiple logistic regression model[1]

	OR (95% CI)[2]	P[3]
Women		
BMI,[4] compared with Q1		
Q2	2.22 (1.33, 3.72)	0.0006
Q3	4.20 (1.74, 10.16)	
Q4	8.55 (2.54, 28.79)	
No. of meals varies, yes compared with no	5.10 (2.17, 11.94)	0.0001
Usual activity, compared with sitting		
Lifting	3.81 (1.12, 12.97)	0.0665
Standing	3.00 (0.95, 9.46)	
Fat (% of energy), compared with Q4		
Q1	4.30 (1.62, 11.42)	0.0022
Q2	2.48 (1.32, 4.55)	
Q3	1.64 (1.18, 2.28)	
Social desirability, compared with Q1		
Q2	1.55 (0.97, 2.47)	0.0565
Q3	2.16 (0.95, 4.88)	
Q4	3.00 (0.93, 9.61)	
Fear of negative evaluation, high compared with low	3.23 (1.35, 7.71)	0.0059
Men		
BMI,[4] compared with Q1		
Q2	2.55 (1.29, 5.05)	0.0103
Q3	4.00 (1.50, 10.71)	
Q4	7.79 (1.82, 33.35)	
Social desirability (low restraint), compared with Q1		
Q2	2.08 (1.28, 3.37)	0.0004
Q3	4.33 (1.65, 11.39)	
Q4	9.02 (1.82, 33.35)	
Social desirability (high restraint), compared with Q1		
Q2	0.68 (0.45, 1.03)	
Q3	0.46 (0.20, 1.05)	
Q4	0.31 (0.09, 1.08)	
Times subject ate per day, <5 compared with ≥5	6.84 (2.50, 18.71)	<0.0001
Restraint (median social desirability), high compared with low	3.57 (1.59, 8.00)	<0.0001
Times dieted, compared with 0		
1–2	1.08 (0.42, 2.78)	0.0030
3–5	0.30 (0.08, 1.10)	
≥6	3.38 (1.02, 11.25)	
Education, compared with high school or less		
Some college	6.29 (0.89, 44.65)	0.0475
College graduate	7.91 (1.09, 57.25)	
Postgraduate	11.38 (1.66, 78.08)	

[1] Q, quartile.
[2] Because analytic distributions for the estimated variables of the final model were unknown, the nominal 95% CIs are presented.
[3] Nominal P value based on likelihood-ratio test statistic. The value given on the first line for each variable corresponds to the overall P value for that variable.
[4] BMI estimates were calculated by using the model estimates for BMI + BMI^2, with the median of the quartile used to generate the OR.

ciated with underreporting of energy intake on the FFQ and 24HRs in both sexes. Variables related to energy balance and characteristics of diet were included in all of the multiple regression models. Psychosocial variables were in 3 of the 4 final models; only the model for men for 24HR contained a variable from the skills and knowledge domain. These results suggest that variables from different domains contribute to reporting accuracy, even after adjustment for the effects of variables from other domains, which highlights the complexity of determinants of dietary misreporting.

Consideration of the variables that were predictive of underreporting in the univariate analyses but were not included in the final models sheds light on the relations between variables. For instance, BMI is significantly correlated with dieting, weight-loss history, and the variables from the Stunkard-Sorensen silhouettes, but BMI explained slightly more of the variability than did these variables in 3 of the 4 multiple regression models, which suggests that the silhouette scores explain a portion of variability similar to that explained by the other variables related to energy balance. For the women's results from the FFQ, both restraint and percentage of energy from fat were related to the probability of underreporting in univariate analyses, yet only percentage of energy from fat remained in the multivariate model. These 2 variables were significantly correlated (P = 0.0005), which suggests that restrained eaters believe that they limit their intake of fat, such that the amount of underreporting attributable to restraint is similar to that attributable to fat intake.

Our results are consistent with those of other studies that found BMI to be predictive of underreporting. However, we found this relation to be nonlinear, leveling out at a BMI > ≈35, which indicates that there may be larger differences in the proportion of underreporters as BMI increases among subjects who have a normal weight or are overweight than among those who are obese. The reason for the association between BMI and underreporting is unclear. Perhaps underreporters have a higher BMI because they lack awareness regarding the type and amount of food that they consume. Our results also confirm previous findings that underreporters are more likely to have a history of dieting, to report a lower percentage of energy from fat, and, for men, to report fewer eating occasions, which suggests omission of snacks or restriction of meals due to dieting.

Social desirability was predictive of underreporting in both the women and the men on the 24HR assessment but not on the FFQ assessment. In contrast with the FFQs, which were filled out by the participants at home, the 24HRs were administered by an interviewer, which perhaps provided those participants with a high drive for social desirability an opportunity to please the interviewer. In the men, the effect of social desirability was modified by restraint. At low levels of social desirability, the restrained eaters were much more likely to underreport than were the unrestrained eaters; when social desirability was high, the likelihood of underreporting did not differ significantly between the restrained and the unrestrained eaters. This may indicate that, because they are conscious of caloric intake, restrained eaters tend to underestimate intake, but, as their desire to please the interviewer increases, they report more accurately. Conversely, unrestrained eaters may report their caloric intake accurately, unless they are concerned about how they are perceived by the interviewer. We found that underreporting was associated with a high fear of negative evaluation in the women. To our knowledge, this scale has not been used previously to predict underreporters and may be worth investigating in future research.

In contrast with other researchers, we did not find a difference in the proportion of underreporters between women and men, although sex differences emerged in the variables that were predictive of underreporting. Additionally, we found no differences in underreporting by age, and education level was included only in the 24HR multiple regression model for the men. The reason for the discrepancies between our results and those of other studies may be the limited age and education range of the study participants. Our sample was also predominantly non-Hispanic white; other ethnic populations have been found to differ from this group in body image (45, 46). Our findings, therefore, might not be generalizable to lower socioeconomic, multiethnic populations or to different age groups.

For the men's results from the FFQ, we found that those who reported that they were less physically active than other men of the same age were less likely to be underreporters, which is contrary to the results of other studies (7, 10–12, 20). Additionally, although the underreporters tended to report higher metabolic equivalents of activity than did the accurate reporters, this difference was not significant. Therefore, a person's perceived activity level may be more closely related to underreporting than is his or her actual activity level. Underreporters may less accurately perceive their activity levels as well as their diets.

Although we were able to fit models that significantly explained a proportion of the variability associated with underreporting, these models still explained less than one-third of the variability; they correctly classified 68–83% of the participants, whereas 50–78% (the prevalence of accurate reporters) were correctly classified without modeling. Our models were best able to predict underreporting on the 24HR; they explained $\geq$20% of the variability, whereas only $\approx$10% was explained on the FFQ. Because the R^2 values from other studies model the degree of underreporting rather than the odds of underreporting for different types of dietary assessments for different study populations, those values are not directly equivalent to ours; however, those values were in the range of 9–30%, which is consistent with our values (6, 7, 10, 14, 22, 47).

For DLW to represent usual energy intake, DLW should be adjusted for long-term weight change. However, adjusting for weight change over a short period only may introduce error into the measurement, because weight change accounts for a small proportion of the within-person weekly fluctuation in energy balance (48). Unadjusted DLW values were used to classify the reporting status of the participants in our analyses, yet there were no differences in this classification whether the 2-wk or 3-mo weight-adjusted DLW measures or unadjusted values were used.

We showed that variables from different domains are related to the accuracy of dietary self-report on FFQs and 24HRs and developed models for men and women for both of these instruments. If highly predictive models of underreporting of energy intake could be developed, additional information could be collected in dietary surveillance and epidemiologic studies of energy balance to identify persons who are more likely to underreport and to adjust for the effects of underreporting. Although we were able to develop significant models, these models may not explain a large enough portion of the variability in the accuracy of underreporting of energy intake to serve this purpose. Future research should focus on studying additional constructs that might explain underreporting; assessing populations that are more diverse in age, race or ethnicity, or weight; and investigating other nutrients with good recovery biomarkers, such as protein. For epidemiologic research in which nutrient intakes are often energy adjusted, assessing systematic errors in the reporting of percentage of energy from protein by using urinary nitrogen and DLW as biomarkers would be useful for adjusting the results of studies of diet and disease. Furthermore, to provide further insight into this important problem, it may be necessary to develop new instruments that better discriminate between accurate reporters and underreporters rather than relying, as we did, on the use of tools developed for different purposes (such as eating disorders).

JAT contributed to the conception of the study, the design of the methods for analyzing the correlates of underreporting, data analysis, data interpretation, and manuscript preparation. AFS, FET, RT, and AS contributed to the conception and conduct of the OPEN study, data interpretation, and manuscript preparation. VK contributed to the conception of the study, the design of the methods for analyzing the correlates of underreporting, data interpretation, and manuscript preparation. None of the authors had any financial or personal conflicts of interest with the research sponsor.

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